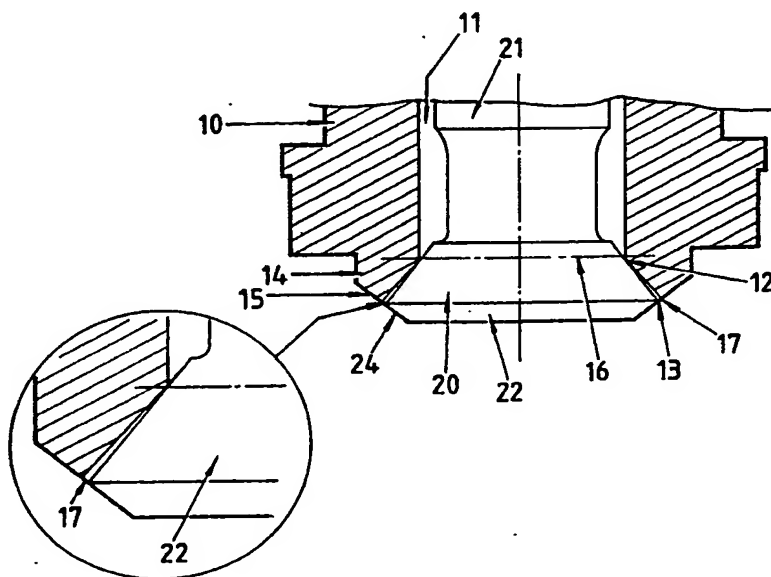




## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

<b>(51) International Patent Classification <sup>5</sup> :</b> <b>F02M 61/08, 61/18, 67/12</b> <b>F01M 69/04</b>	<b>A1</b>	<b>(11) International Publication Number:</b> <b>WO 91/11609</b> <b>(43) International Publication Date:</b> 8 August 1991 (08.08.91)
<b>(21) International Application Number:</b> PCT/AU91/00027 <b>(22) International Filing Date:</b> 23 January 1991 (23.01.91) <b>(30) Priority data:</b> PJ 8341 26 January 1990 (26.01.90) AU <b>(71) Applicant (for all designated States except US):</b> ORBITAL ENGINE COMPANY PROPRIETARY LIMITED [AU/AU]; 1 Whipple Street, Balcatta, W.A. 6021 (AU). <b>(72) Inventors; and</b> <b>(75) Inventors/Applicants (for US only) :</b> DAVIS, Robert, Max [AU/AU]; 137 Crawford Road, Maylands, W.A. 6051 (AU). DASILVA, Jorge, Manuel, Pereira [AU/AU]; 47 St. Leonards Avenue, West Leederville, W.A. 6007 (AU).		<b>(74) Agent:</b> WATERMARK; 1st Floor, The Atrium, 290 Bur- wood Road, Hawthorn, VIC 3122 (AU).  <b>(81) Designated States:</b> AT (European patent), AU, BE (Euro- pean patent), BR, CA, CH (European patent), DE (Eu- ropean patent), DK (European patent), ES (European patent), FR (European patent), GB (European patent), GR (European patent), HU, IT (European patent), JP, KR, LU (European patent), NL (European patent), SE (European patent), SU, US.  <b>Published</b> <i>With international search report.</i>

**(54) Title:** FUEL INJECTOR NOZZLE**(57) Abstract**

An internal combustion engine fuel injector having a selectively openable nozzle (10) through which fuel is delivered to a combustion chamber of the engine. The nozzle (10) comprises a port (12) having an internal annular surface (13) and a valve member (20) having an external annular surface co-axial with respect to the internal annular surface. The annular surfaces being shaped so that when the internal and external annular surfaces are in sealing contact closing the nozzle the maximum width (17) of the passage between the said surfaces is not substantially more than 40 microns, preferably not more than 20 microns, in the direction normal to said surfaces.

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## FUEL INJECTOR NOZZLES

This invention relates to a valve controlled nozzle for the injection of fuel in an internal combustion engine. In this specification the term "internal combustion engine" is to be understood to be limited to engines having an intermitent combustion cycle, such as reciprocating or rotary engines, and does not include continuous combustion engines such as turbines.

The characteristics of the spray of fuel delivered from a nozzle to an internal combustion engine, such as directly into the combustion chamber, have a major affect on the efficiency of the burning of the fuel, which in turn affects the stability of the operation of the engine, the engine fuel efficiency and the composition of the engine exhaust gases. To optimise these effects, particularly in a spark ignited engine, the desirable characteristics of the spray pattern of the fuel issuing from the nozzle include small fuel drop size (liquid fuels), controlled geometry and penetration of the fuel spray, and, at least at low engine loads, a relatively contained and evenly distributed ignitable cloud of fuel vapour in the vicinity of the engine spark plug.

Some known injection nozzles, used for the delivery of fuel directly into the combustion chamber of an engine, are of the poppet valve type, which delivers the fuel in the form of a cylindrical or divergent conical spray. The nature of the shape of the fuel spray is dependent on a number of factors including the geometry of the port and valve constituting the nozzle, especially the surfaces of the port and valve immediately adjacent the seat where the port and valve engage to seal when the nozzle is closed. Once a nozzle geometry has been selected to give the required performance, relatively minor departures from that geometry can significantly impair that performance.

In particular the attachment or build-up of solid combustion products or other deposits on the surfaces over

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which the fuel flows can be detrimental to the correct performance of the nozzle. The principal cause of build up on these surfaces is the adhesion thereto of carbon related or other particles that may be produced by the combustion or partial combustion of residual fuel left on these surfaces between injection cycles, or by carbon related particles produced in the combustion chamber during combustion.

The buildup of deposits on these surfaces can also adversely affect the metering performance of an injector nozzle where the metering of the fuel is carried out at the injector nozzle. The existence of deposits can directly reduce the cross-sectional area of the fuel path through the nozzle when open, and/or cause eccentricity between the valve and the port of the nozzle thereby varying the cross-sectional area of the fuel path. The extent of these deposits can also be such that correct closing of the injector nozzle cannot be achieved and can thus lead to continuous leakage of fuel through the nozzle into the combustion chamber. This leakage would have severe adverse effects on the emission level in the exhaust gases, as well as instability in the engine operation.

It is therefore an object of the present invention to provide a nozzle, through which fuel is injected in an internal combustion engine, that will contribute to a reduction in the build up of deposits in the path of fuel being delivered to the engine, and hence improve the performance of the nozzle while in service.

With this object in view there is provided an internal combustion engine fuel injector having a selectively openable nozzle through which fuel is delivered to a combustion chamber of the engine, said nozzle comprising a port having an internal annular surface and a valve member having an external annular surface co-axial with respect to the internal annular surface, said valve element being axially movable relative to the port to selectively provide between said internal and external

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annular surfaces a continuous passage for the delivery of fuel therethrough or sealing contact therebetween along a circular seat line substantially co-axial to the respective annular surfaces to prevent the delivery of fuel therebetween, said annular surfaces being relatively configured so that when the internal and external annular surfaces are in sealing contact along said circular seat line the maximum width of the passage between the said surfaces to either side of the seat line is not substantially more than 40 microns in the direction normal to said surfaces.

Conveniently the maximum width of the passage is located downstream from the seat line with respect to the direction of flow of fuel through the passage.

The maximum width of the passage is preferably not substantially more than about 35 microns and preferably not substantially more than about 30 microns.

Preferably the body in which the port is formed and the valve member have respective terminal faces at the downstream end of the internal and external annular surfaces that are substantially normal to the respective annular surfaces. Preferably the terminal faces are substantially at right angles plus or minus  $10^\circ$  to the respective annular surfaces.

Conveniently the terminal faces of the body and valve member are substantially co-planar when the valve member is seated in sealing contact against the port along the circular seat line, or at least neither of the annular surfaces substantially overhang or extend beyond the extremity of the other at the downstream end, when the valve member is seated.

The length of at least one of the internal and external annular surfaces is preferably between about 0.50 and 2.0 mm and conveniently between 0.80 and 1.50 mm.

Conveniently the internal and external annular surfaces are inclined to the common axis thereof at

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respective angles so that they diverge from the circular seat line down stream in the direction of flow of the fuel during delivery.

5 The circular seat line can be located substantially at or adjacent the inner or smaller diameter end of the internal annular surface of the port.

10 The internal and external annular surface can conveniently be of truncated conical form, although the external annular surface of the valve member may be arcuate in axial section presenting a convex conveniently part spherical face to the internal annular surface of the port. The use of the convex face does assist in manufacture in obtaining the desired location of the circular seat line sealing between the port and valve member.

15 The above described relationship of the internal and external surfaces has been proved in testing to maintain the desired spray formation and desired performance of the nozzle over longer periods than previously achieved. It is suggested that the reduced maximum dimension of the gap  
20 between the annular surfaces downstream of the circular seat line may generate an impact load on any deposit each time the nozzle closes. This impact load dislodging the deposit and so preventing the build-up of deposits on the opposed surfaces.

25 Also the arranging of the terminal surfaces of the port and valve member substantially at right angles to the respective annular surfaces, results in any extension of deposits on the terminal surfaces into the path of the fuel being in the direct path of the fuel and so subject to the maximum impingment force from the fuel to break off such  
30 deposit extensions. The development of such overhanging deposits is also inhibited by the respective terminal facing being co-planar when the valve member is seated in the port.

35 The invention will be more readily understood from the following description of three practical arrangements of a fuel injector nozzle incorporating an embodiment of the

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present invention as illustrated in the accompanying drawings.

In the drawings:

5 Figure 1 is an axial section view of a nozzle port and valve in the closed position;

Figure 2 is a view as in Figure 1 with the valve in the open position;

Figure 3 is a view as in Figure 1 with an alternative valve configuration;

10 Figure 4 is a view as in Figure 1 with a further alternative valve configuration;

Referring now to Figures 1 and 2, the nozzle body 10 has in the lower portion thereof an axial bore 11 therethrough terminating in a port 12, having an internal annular surface 13. Surrounding the port 12 is a projecting ring 14 having a terminal surface 15 which intersects the internal annular surface 13 at right angles.

20 The valve member 20 has a stem 21 with an integral valve head 22 at one end. The stem 21 co-operates with a suitable mechanism to axially reciprocate in the nozzle body 10 to selectively open and close the nozzle. Fuel, preferably entrained in a gas such as air, is supplied through the bore 11 to be delivered to an engine when the nozzle is open. The fuel may be metered as it is delivered through the nozzle or may be supplied in metered quantities to the bore 11.

30 The valve head 22 has an external annular surface 23, diverging outwardly from the stem 21, and a terminal face 24 converging from the extremity of the annular surface 23. The surfaces 23 and 24 are each of truncated conical form and intersect at right angles.

35 The cone angle of the annular surface 23 is less than that of the annular surface 13 so they diverge with respect to each other in the direction towards the terminal faces 15 and 24 respectively. The angles and diameters of

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the surfaces 13 and 23 are selected so that the valve head 22 is seated at the junction of the bore 11 and the internal annular surface 13 of the port 12. The circular seat line is indicated on the valve head 22 at 16. The length of the surfaces 13 and 23 are selected so that when the valve head 22 is seated in the port 12, the respective terminal surfaces 15 and 24 are aligned. This can conveniently be achieved by grinding these surfaces after assembly of the valve member to the nozzle body.

The selection of the angles of the annular surfaces 13 and 23 and the length of each downstream of the seat line 16 determines the width of the annular gap 17 between them at the extremity thereof. In order to achieve the advantage of controlling the build up of deposits between these surfaces, the width of the annular gap 17, when the valve member 20 is seated, is not to be substantially more than 40 microns. This can also be achieved by grinding the terminal faces 15 and 24 after assembly.

In one practical form of the nozzle, the cone angles of the internal annular surface 13 and external annular surface 23 are  $40^\circ$  and  $39^\circ$  respectively, with the bore 11 nominally 4.20 mm diameter and the maximum diameter of the outer end of the valve head 22 nominally 5.90 mm. These dimensions result in the gap 17 being about 20 microns at the lower extremity, with the length of the internal surface 13 of the port being 1.35 mm.

It is to be understood that other nominal seat angles for the nozzle can be used and may be within the range of  $20^\circ$  to  $60^\circ$ , preferably in the range  $30^\circ$  to  $50^\circ$ . Also the length of the internal surface 13 of the port should not exceed 2.00 mm and is preferably between 0.8 and 1.5 mm.

In the alternative construction as shown in Figure 3, the only variation from that shown in Figures 1 and 2 is that the external annular surface 33 of the valve head is not conical as in Figures 1 and 2, but is convex,



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conveniently arcuate, in cross-section. The contour of the convex annular surface is selected in relation to the internal annular surface 13 to locate the circular seat line 32 is spaced from the junction of the bore 11 and internal surface 13, and so the gap between the internal and external surfaces 13 and 33 progressively increase from the seat line 32 to the terminal face 34. Again the width of the gap 31 at the terminal face 34 is of the order of 20 to 30 microns when the valve member is seated. The convex surface may be part of a sphere or a blend of two or more part-spherical surfaces, and is symmetrical with respect to the axis of the valve member 20. In a further modification, the internal annular surface of the port is concave with the external annular surface of the valve head is convex.

In a further embodiment of the invention, the annular surfaces of valve member 20 and port 10 are configured so that the seat line is adjacent the outer or downstream extremity of the internal annular surface of the port. This construction is shown in Figure 4, wherein the internal annular surface 43 of the port 10 and external annular surface 44 of the valve member 10 are each of truncated conical shape. The cone angle of the external annular surface 44 is greater than that of the internal annular surface 43 so that the surface contact is at or adjacent the lower ends thereof along the seat line 45. Thus the passage 46 between the surfaces 43 and 44 extend upstream from the seat line 45 to the location of maximum width 47. Again the internal and/or external annular surfaces may be convex or concave as above discussed.

Also in the embodiment shown in Figure 4 the terminal face 48 of the port is substantially inclined to the terminal face 49 of the valve member. The configuration of the terminal faces may also be incorporated in the embodiment as shown in Figures 1 to 3 and likewise the configuration shown in Figures 1 to 3 may be incorporated in the embodiment shown in Figure 4. The rearwardly inclined face 48 results in only a relatively small mass of metal at

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the tip of the body which will in use maintain a high temperature and therefore burn off any particles deposited thereon.

5 Each of the embodiments of the nozzle described have an outwardly opening valve member, commonly referred to as a poppet valve, however, the invention is equally applicable to inwardly opening valve members, commonly referred to as pintel valves.

10 The above described nozzle may be used in any form of fuel injector using a poppet type valve, and may be used for injecting either liquid or gaseous fuels, alone or in combination, and with or without entrainment in a gaseous carrier, such as compressed air

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THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. An internal combustion engine fuel injector having a selectively openable nozzle through which fuel is delivered to a combustion chamber of the engine, said nozzle comprising a port having an internal annular surface and a valve member having an external annular surface co-axial with respect to the internal annular surface, said valve element being axially movable relative to the port to selectively provide between said internal and external annular surfaces a continuous passage for the delivery of fuel therethrough or sealing contact therebetween along a circular seat line substantially co-axial to the respective annular surfaces to prevent the delivery of fuel therebetween, said annular surfaces being relatively configured so that when the internal and external annular surfaces are in sealing contact along said circular seat line the maximum width of the passage between the said surfaces to either side of the seat line is not substantially more than 40 microns in the direction normal to said surfaces.
2. A fuel injector as claimed in claim 1, wherein the said maximum width of the passage is located downstream from the seat line with respect to the direction of flow of fuel through the passage.
3. A fuel injector as claimed in claim 2, wherein the seat line is located adjacent the upstream end of the passage.
4. A fuel injector as claimed in claim 1 wherein the seat line is located adjacent the downstream end of the passage with respect to the direction of flow of fuel through the passage.

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5. A fuel injector as claimed in claim 2 or 3, wheein the internal and external annular surfaces diverge from the seat line with the maximum width of the passage at the downstream extremity thereof.

6. A fuel injector as claimed in any one of claims 1 to 5, wherein at least one of the annular surfaces are of truncated conical shape.

7. A fuel injector as claimed in any one of claims 1 to 5, wherein at least one of the annular surfaces are of part spherical shape co-axial to the two annular surfaces.

8. A fuel injector as claimed in any one of claims 1 to 7, wherein said maximum width of the passage is not more than about 35 microns.

9. A fuel injector as claimed in any one of claims 1 to 7, wherein said maximum width of the passage is not more than about 30 microns.

10. A fuel injector as claimed in any one of claims 1 to 7, wherein said maximum width of the passage is not more than about 20 microns.

11. A fuel injector as claimed in any one of claims 1 to 10, wherein at least one of said annular surfaces has a length between about 0.50 and 2.00 mm.

12. The fuel injector as claimed in any one of claims 1 to 10, wherein at least one of said annular surfaces has a length between about 0.8 and 1.50 mm.

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13. A fuel injector as claimed in any one of claims 1 to 12, wherein at least one of the port or valve members has a terminal face at the downstream end of the annular surface thereof that is substantially normal to said annular surface.

14. A fuel injector as claimed in any one of claims 1 to 13, wherein both the port and valve member have a terminal face at the downstream end of the respective annular surfaces, said terminal faces being substantially co-planar when the two annular surfaces are in contact along the seat line.

(b<sub>1</sub>)

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Fig 1.

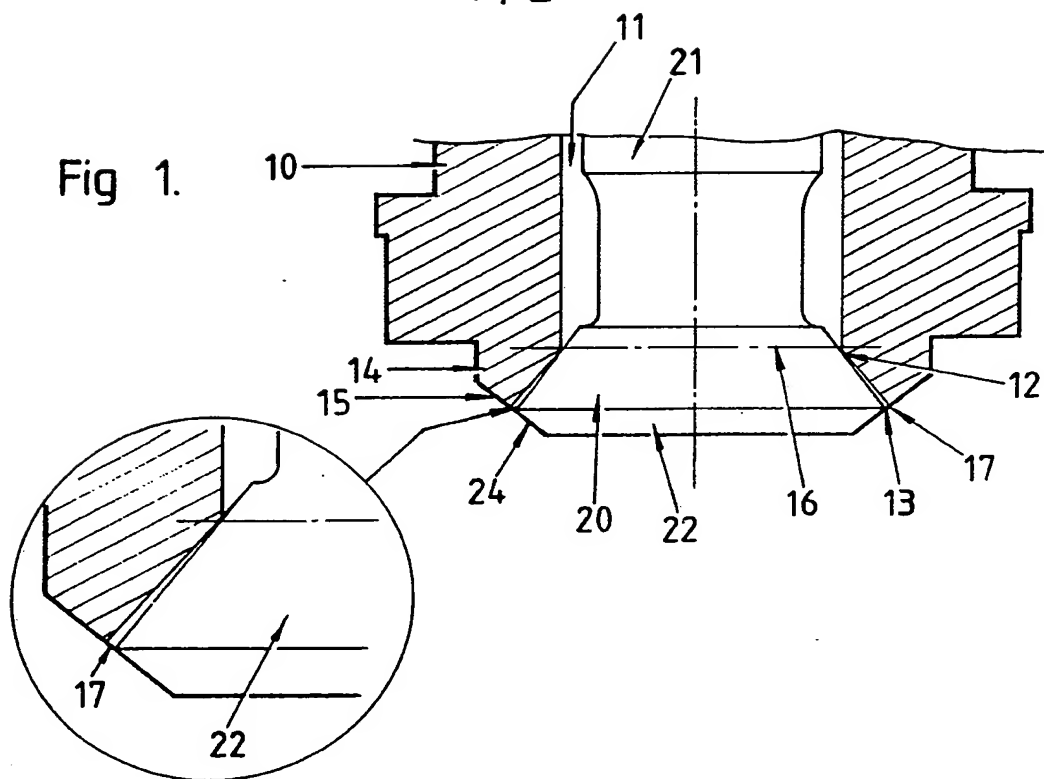
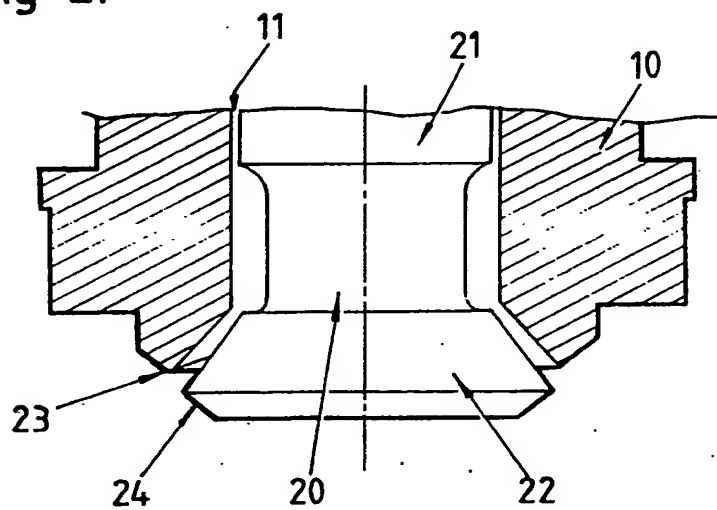


Fig 2.



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Fig 3.

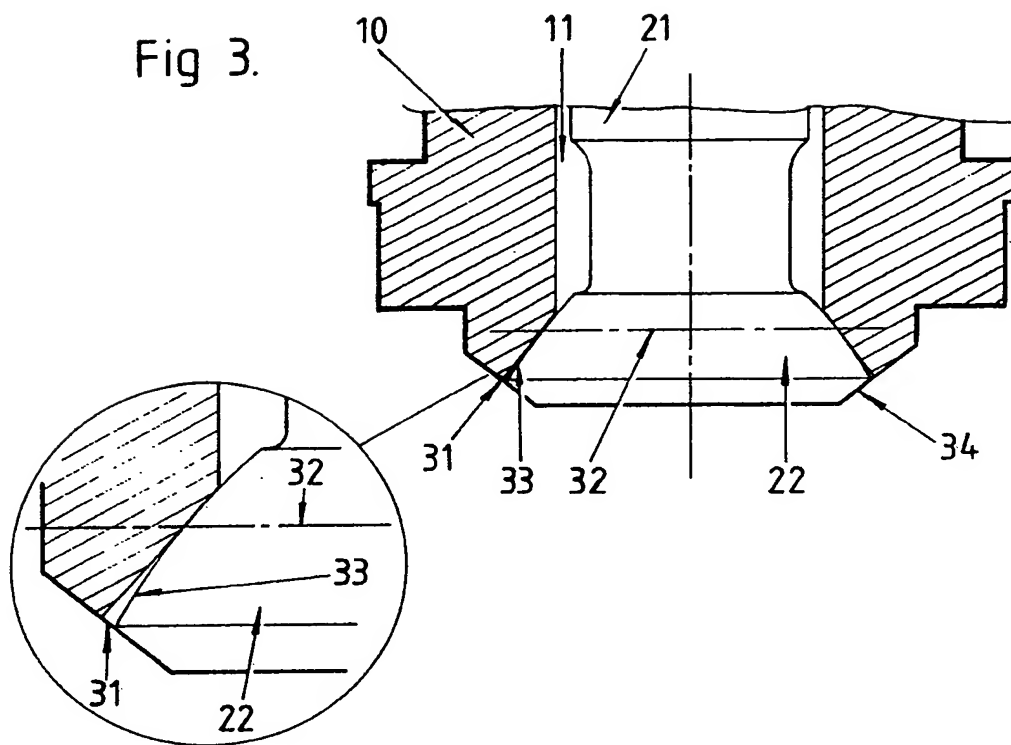
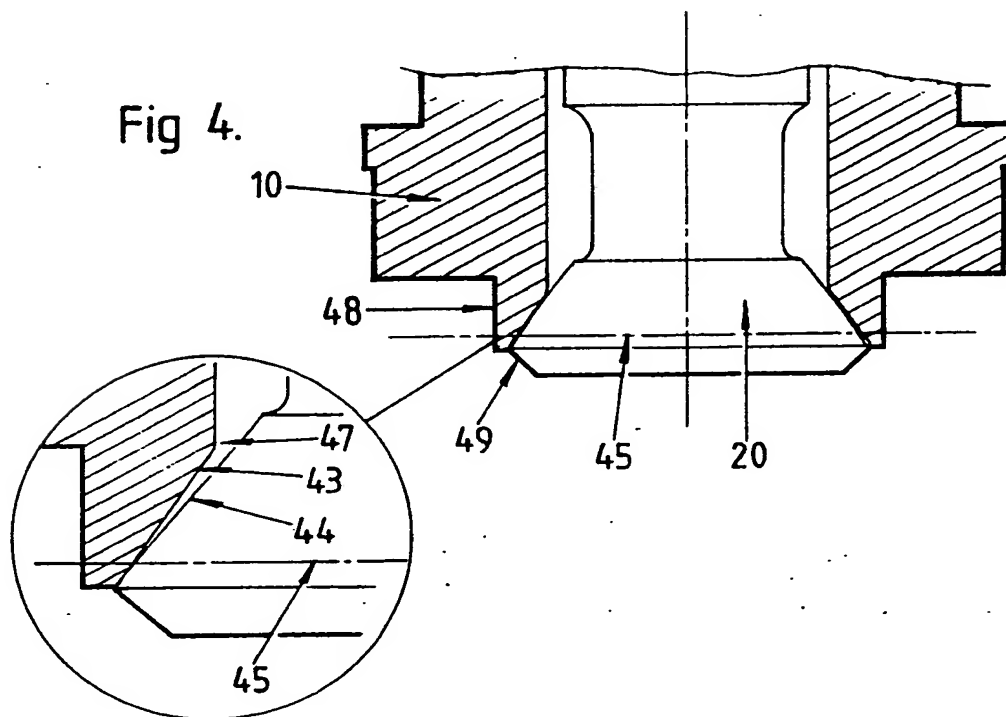


Fig 4.



<b>I. CLASSIFICATION OF SUBJECT MATTER</b> (if several classification symbols apply, indicate all) 6				
According to International Patent Classification (IPC) or to both National Classification and IPC				
Int. Cl. <sup>5</sup> F02M 61/08, 61/18, 67/12, 69/04				
<b>II. FIELDS SEARCHED</b>				
Minimum Documentation Searched 7				
Classification System	Classification Symbols			
IPC	F02M 61/08, 61/18, 67/12, 69/04			
Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched 8				
AU: IPC as above				
<b>III. DOCUMENTS CONSIDERED TO BE RELEVANT</b> 9				
Category*	Citation of Document, <sup>11</sup> with indication where appropriate, of the relevant passages <sup>12</sup>	Relevant to Claim No 13		
A	GB,A, 2146068 (LUCAS INDUSTRIES plc (UNITED KINGDOM)) 11 April 1985 (11.04.85)			
<p>* Special categories of cited documents: 10</p> <table style="width: 100%;"> <tr> <td style="width: 50%;"> <p>"A" document defining the general state of the art which is not considered to be of particular relevance</p> <p>"E" earlier document but published on or after the international filing date</p> <p>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</p> <p>"O" document referring to an oral disclosure, use, exhibition or other means</p> <p>"P" document published prior to the international filing date but later than the priority date claimed</p> </td> <td style="width: 50%;"> <p>"T" Later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</p> <p>"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step</p> <p>"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.</p> <p>"&amp;" document member of the same patent family</p> </td> </tr> </table>			<p>"A" document defining the general state of the art which is not considered to be of particular relevance</p> <p>"E" earlier document but published on or after the international filing date</p> <p>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</p> <p>"O" document referring to an oral disclosure, use, exhibition or other means</p> <p>"P" document published prior to the international filing date but later than the priority date claimed</p>	<p>"T" Later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</p> <p>"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step</p> <p>"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.</p> <p>"&amp;" document member of the same patent family</p>
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<b>IV. CERTIFICATION</b>				
Date of the Actual Completion of the International Search 5 April 1991 (05.04.91)		Date of Mailing of this International Search Report 22 April 1991		
International Searching Authority  Australian Patent Office		Signature of Authorized Officer  C M WYATT		



## FURTHER INFORMATION CONTINUED FROM THE SECOND SHEET

V. ☐ OBSERVATIONS WHERE CERTAIN CLAIMS WERE FOUND UNSEARCHABLE 1

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claim numbers ..., because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claim numbers ..., because they relate to parts of the international application that do comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☐ Claim numbers ..., because they are dependent claims and are not drafted in accordance with the second and third sentences of PCT Rule 6.4 (a):

VI. ☐ OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING 2

This International Searching Authority found multiple inventions in this international application as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims of the international application.
2. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims of the international application for which fees were paid, specifically claims:
3. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claim numbers:
4. ☐ As all searchable claims could be searched without effort justifying an additional fee, the International Searching Authority did not invite payment of any additional fee.

## Remark on Protest

- ☐ The additional search fees were accompanied by applicant's protest.  
☐ No protest accompanied the payment of additional search fees.

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)

Category*	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No

FURTHER INFORMATION CONTINUED FROM THE FIRST SHEET  
(Not for publication)